Single-frequency Er/Yb Co-doped Waveguide Lasers

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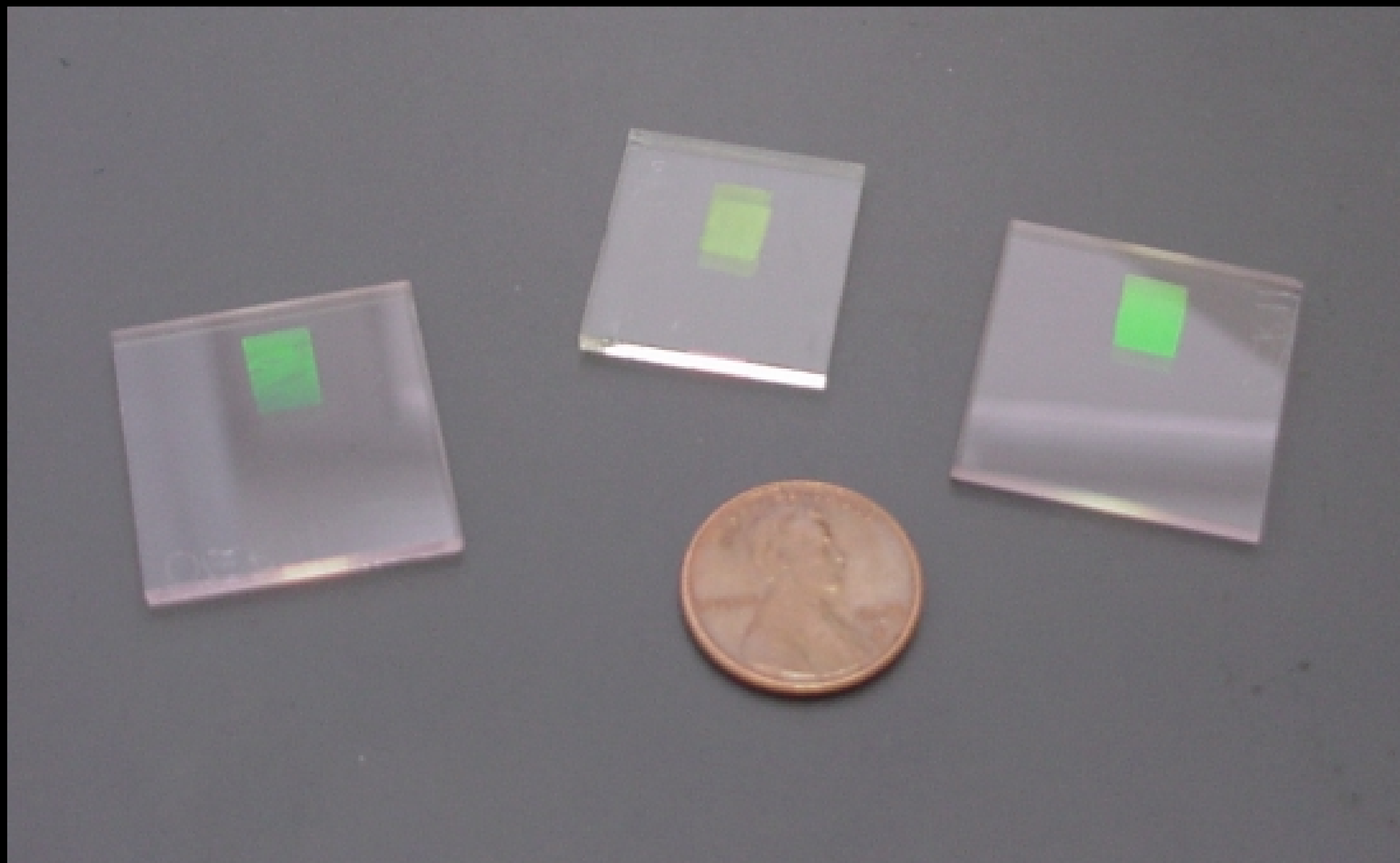
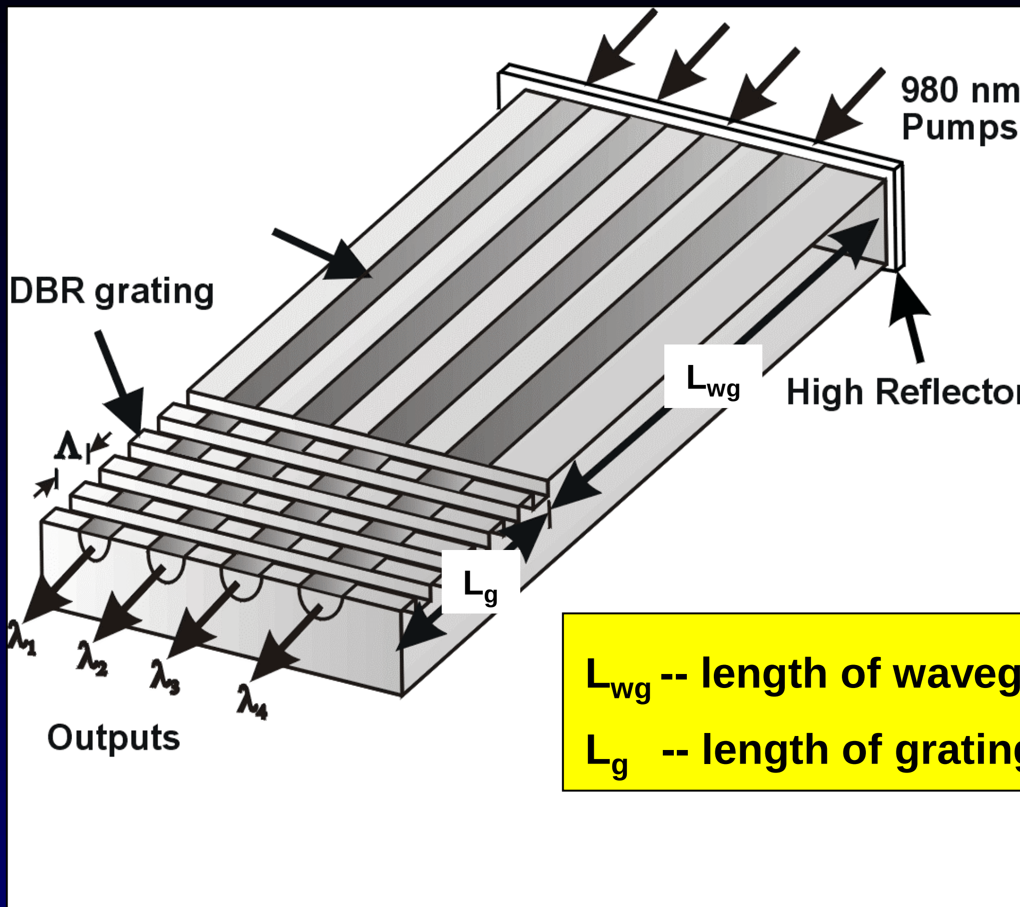
Single-Frequency DBR Lasers



Single-frequency DBR Laser



L_{wg} -- length of waveguide (15-20 mm)

L_g -- length of grating (6mm)

Why Waveguide Lasers?

High rare-earth-doping concentrations

- High power from compact, monolithic package
- Simple environmental isolation

Long upper-state lifetime of laser transition

- ~10ms → longer than semiconductors (ns)
  → leads to narrower linewidth < 10 kHz

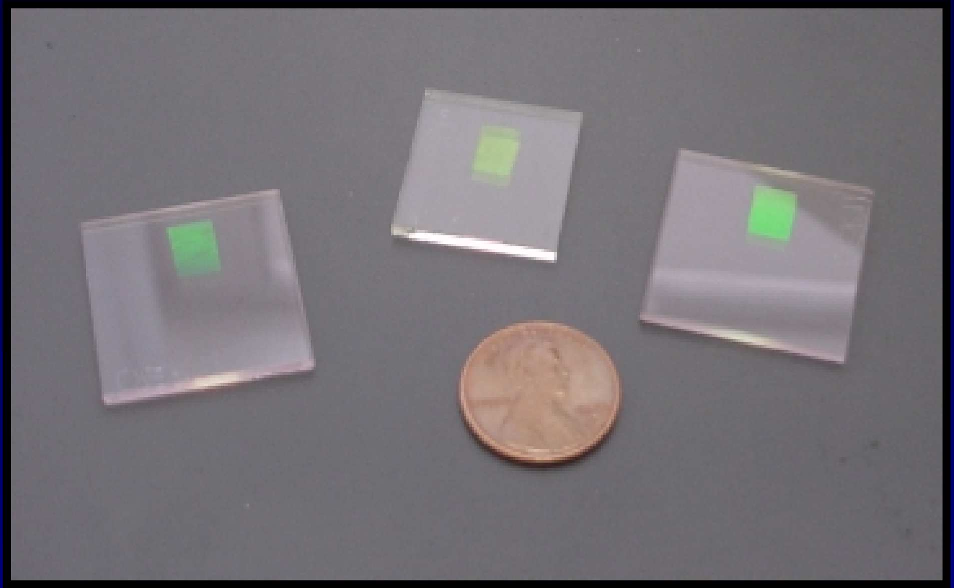
Mechanical & thermal stability

- Reduced microphonic noise
  → environmental isolation

Easily integrated into fiber-based systems

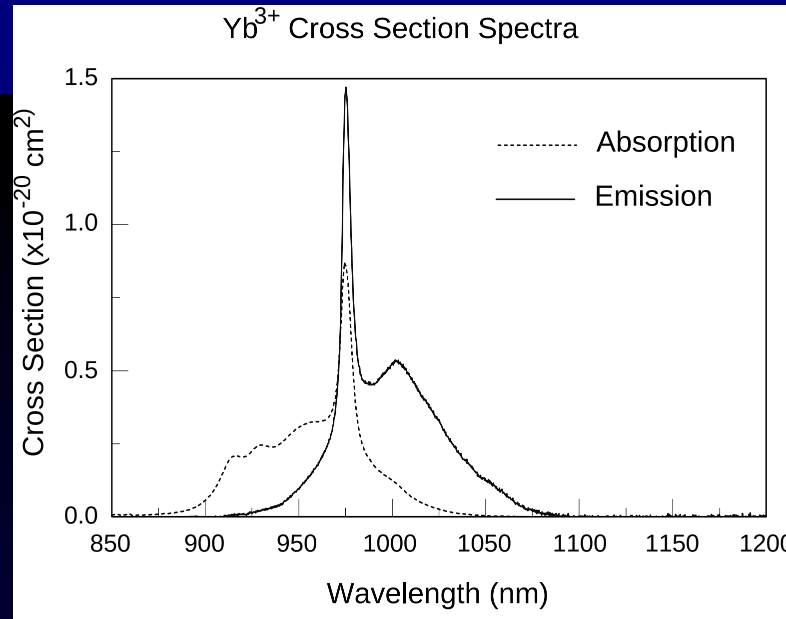
Applications

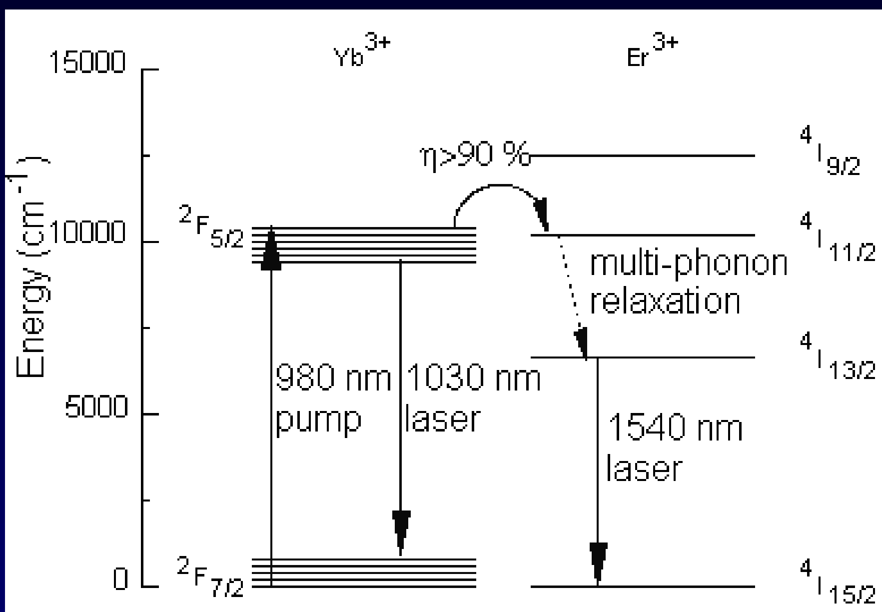
- All optical microwave and RF signal generation.
- Laser sources for photonic crystal cavities.
- Remote sensing and ranging.
- High-speed detector testing.
- Semiconductor laser characterization.
- Optical frequency synthesis and metrology.
- Telecommunications.

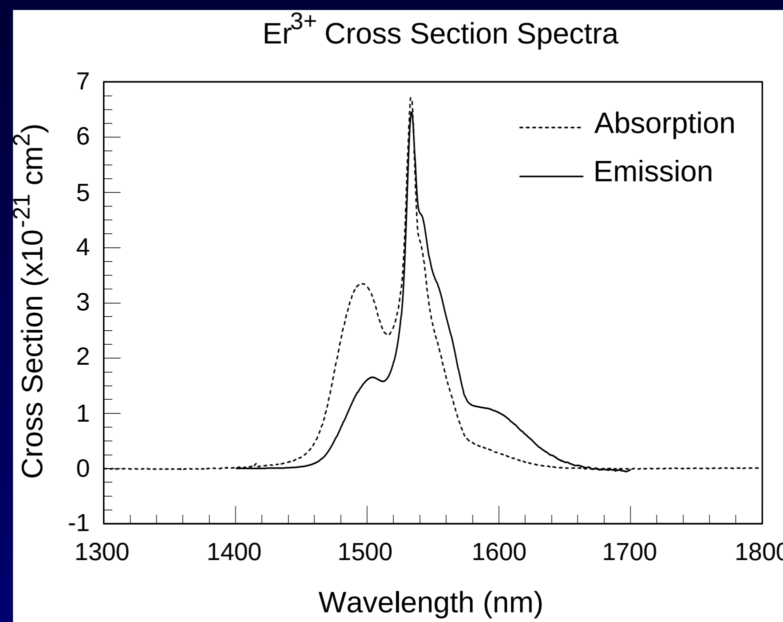


Spectroscopic Properties Of Er^{3+} and Yb^{3+} in Phosphate glass

Typical Dopant Levels:
1×10^{20} /cm^3 for Er^{3+}
4×10^{20} /cm^3 for Yb^{3+}

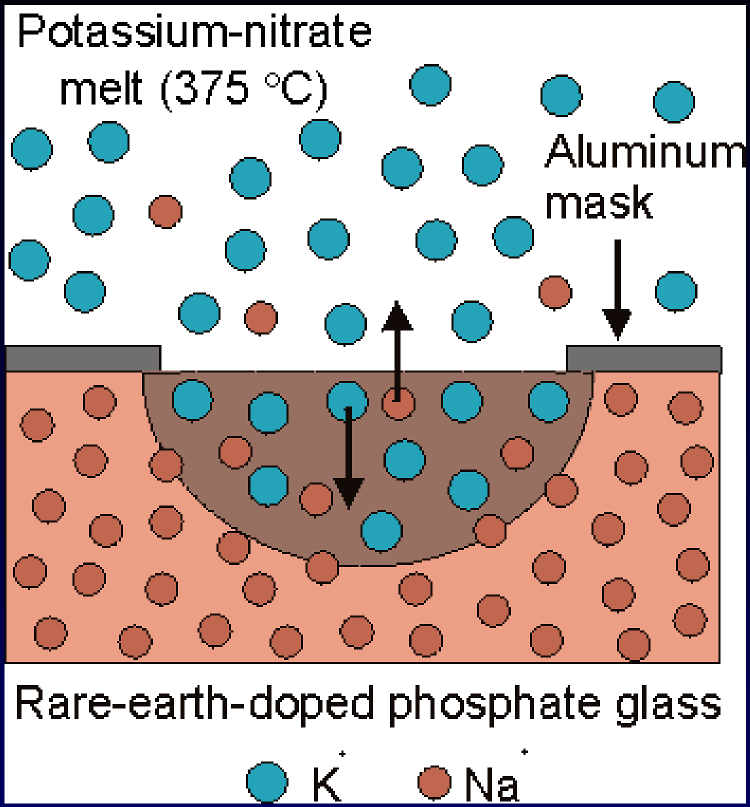






Ion Exchange Process

- **Yb/Er-codoped phosphate glass host**
- **K^+-Na^+ ion exchange**
  - -KNO_3 melt @ 375 °C
  - -4 hours
- **Dice & Polish waveguide end facets**
- **Remove Aluminum Mask**



DBR Fabrication

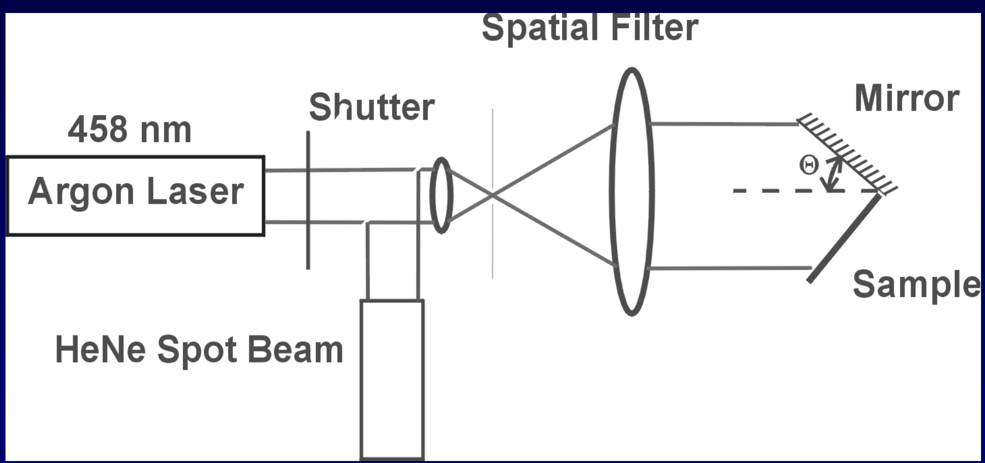
- Holographic exposure of photoresist
  - 0.5 µm thick photoresist
  - 1st order diffraction maximized during developing
- Ar ion sputter etch to transfer grating

Grating Period Defined by:

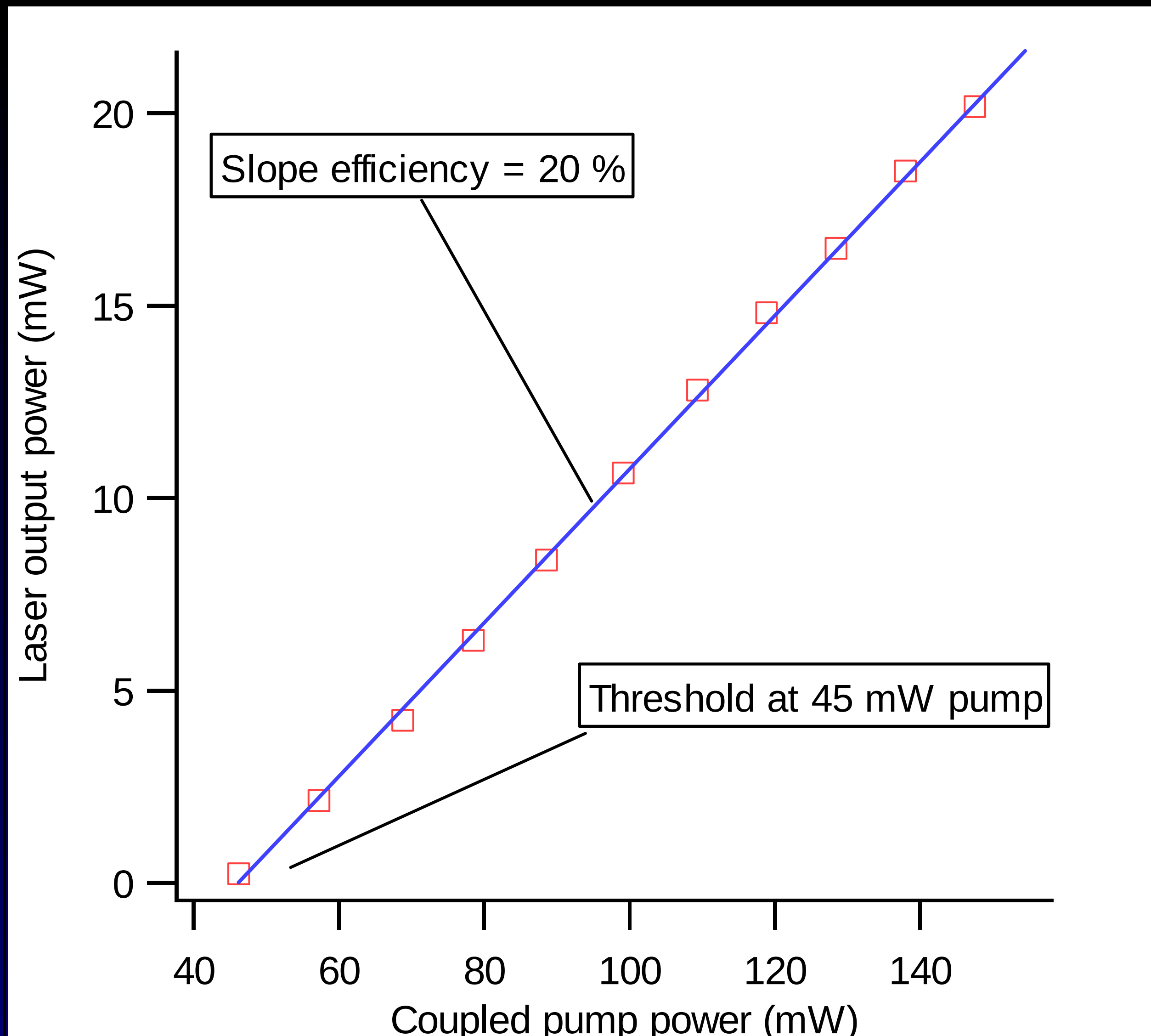
$$\Lambda = \frac{\lambda_0}{2N_{eff}} = \frac{\lambda_{exp}}{2n\sin\theta_{exp}}$$

Exposure Angle

$$\theta_{exp} = \sin^{-1}\left(\frac{N_{eff}\,\lambda_{exp}}{n_{air}\lambda_0}\right)$$



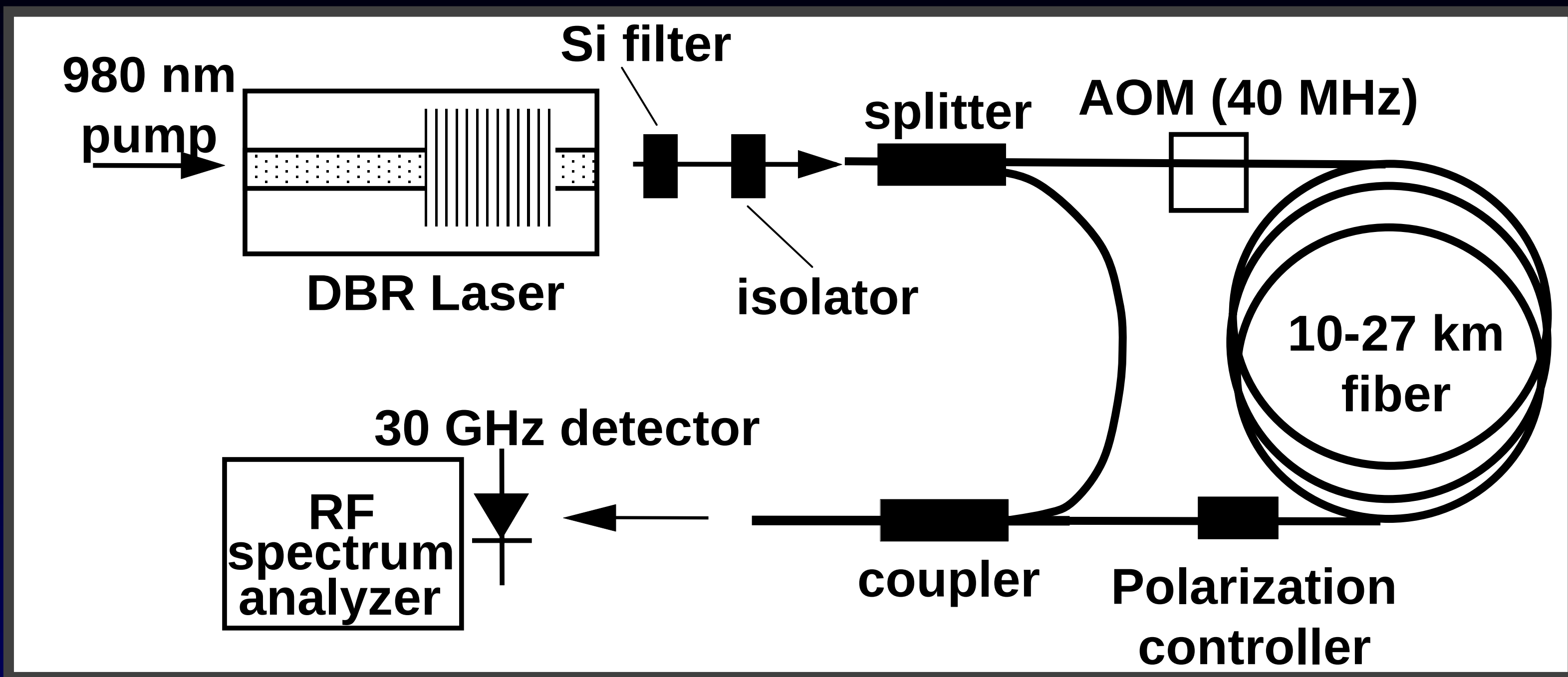
DBR Laser Output Power



Over 80 mW with higher power pump laser

Linewidth Measurement

Delayed Self-heterodyne

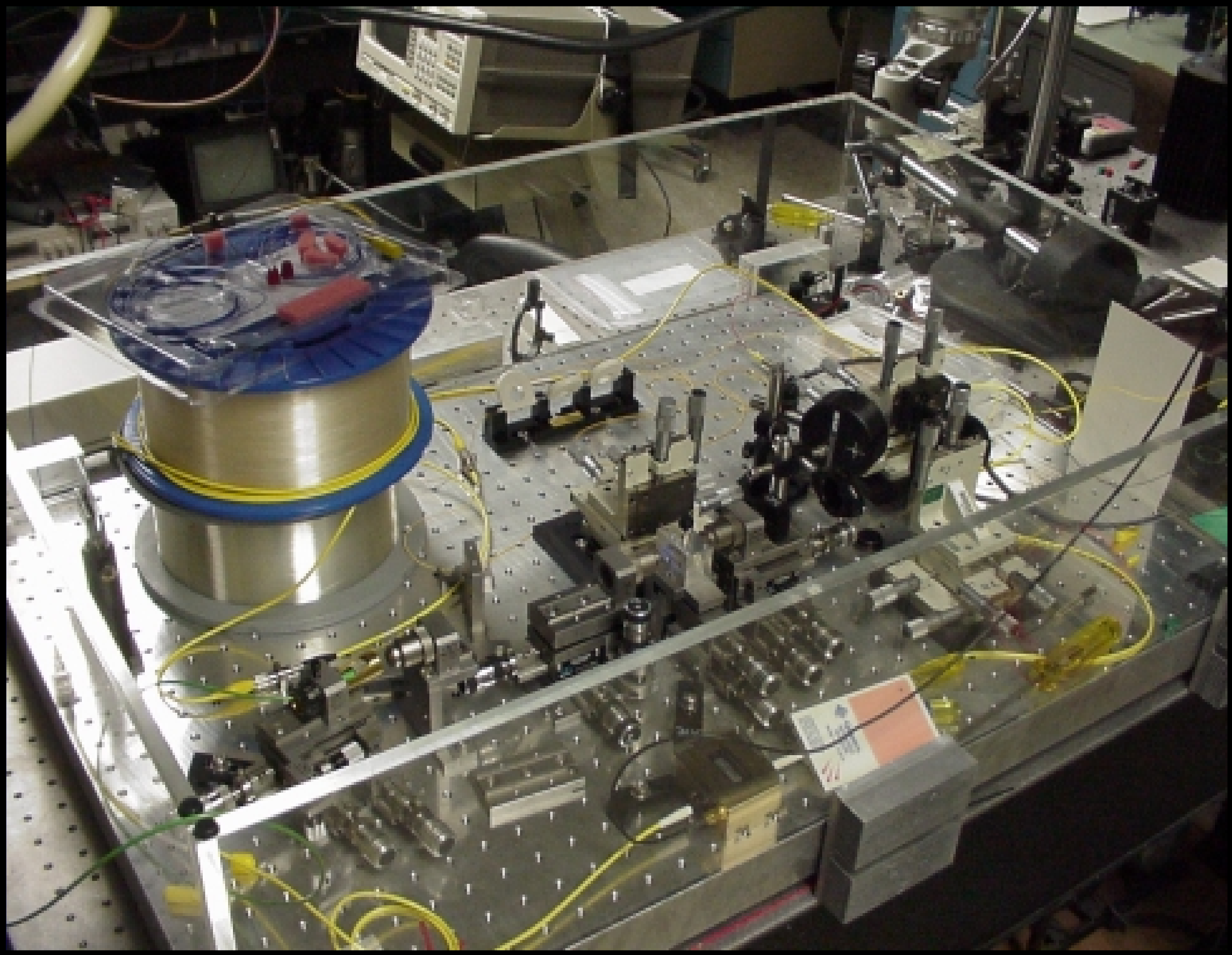


Lorentzian

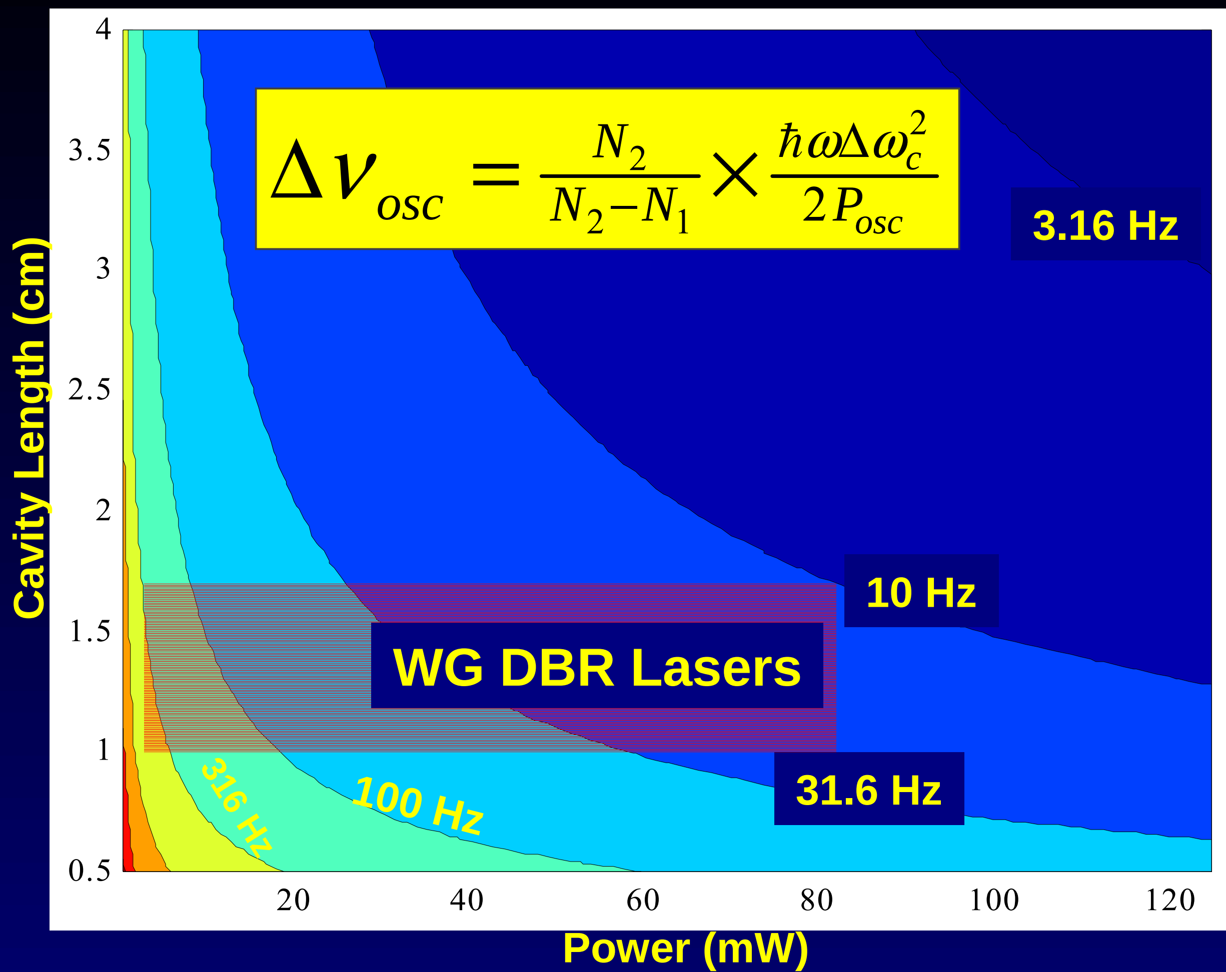
$$\tau_c = \frac{1}{\pi \cdot \Delta \nu}$$

Resolution
$\Delta\nu$ = 2.4 kHz

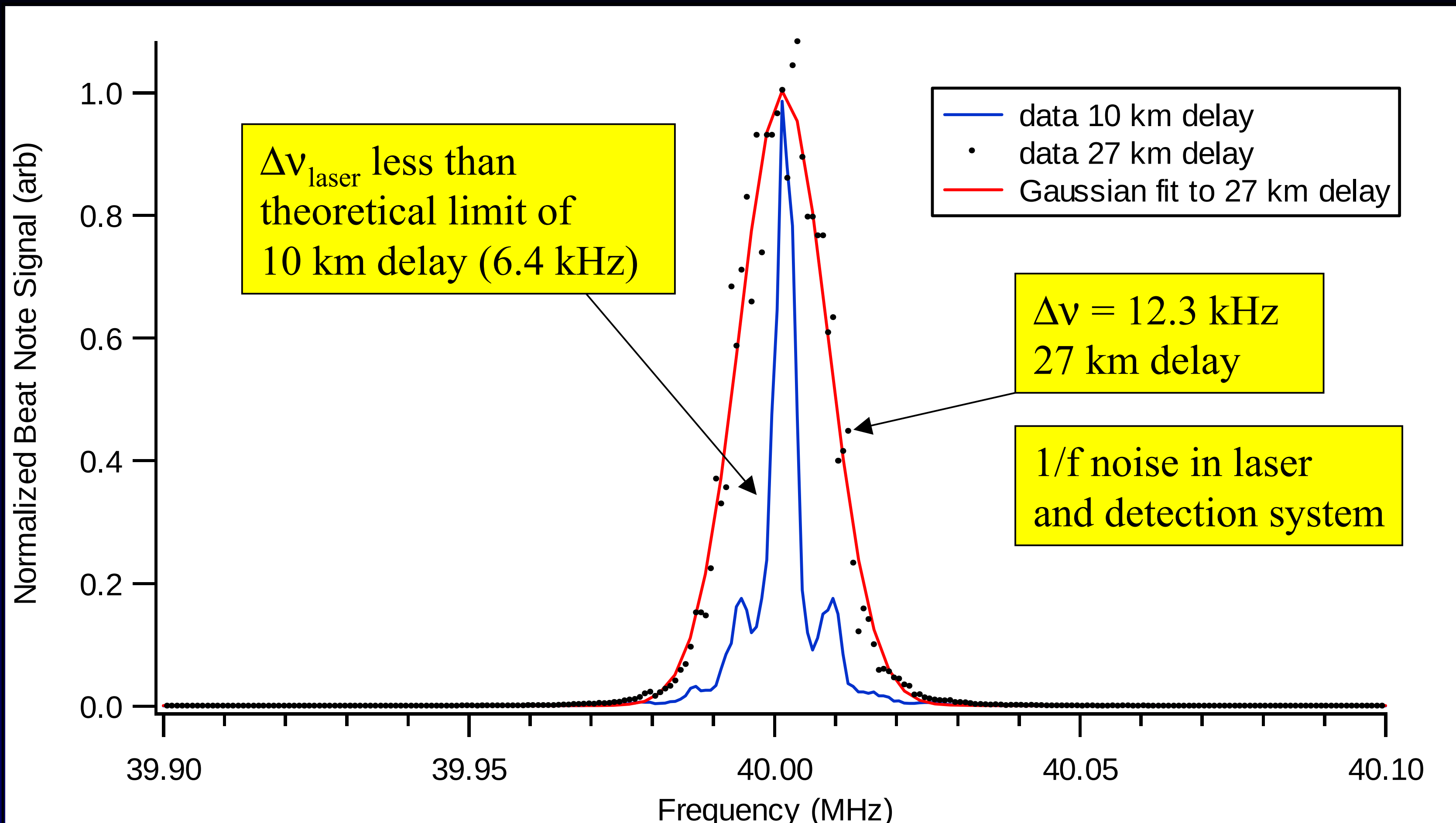
Linewidth Measurement



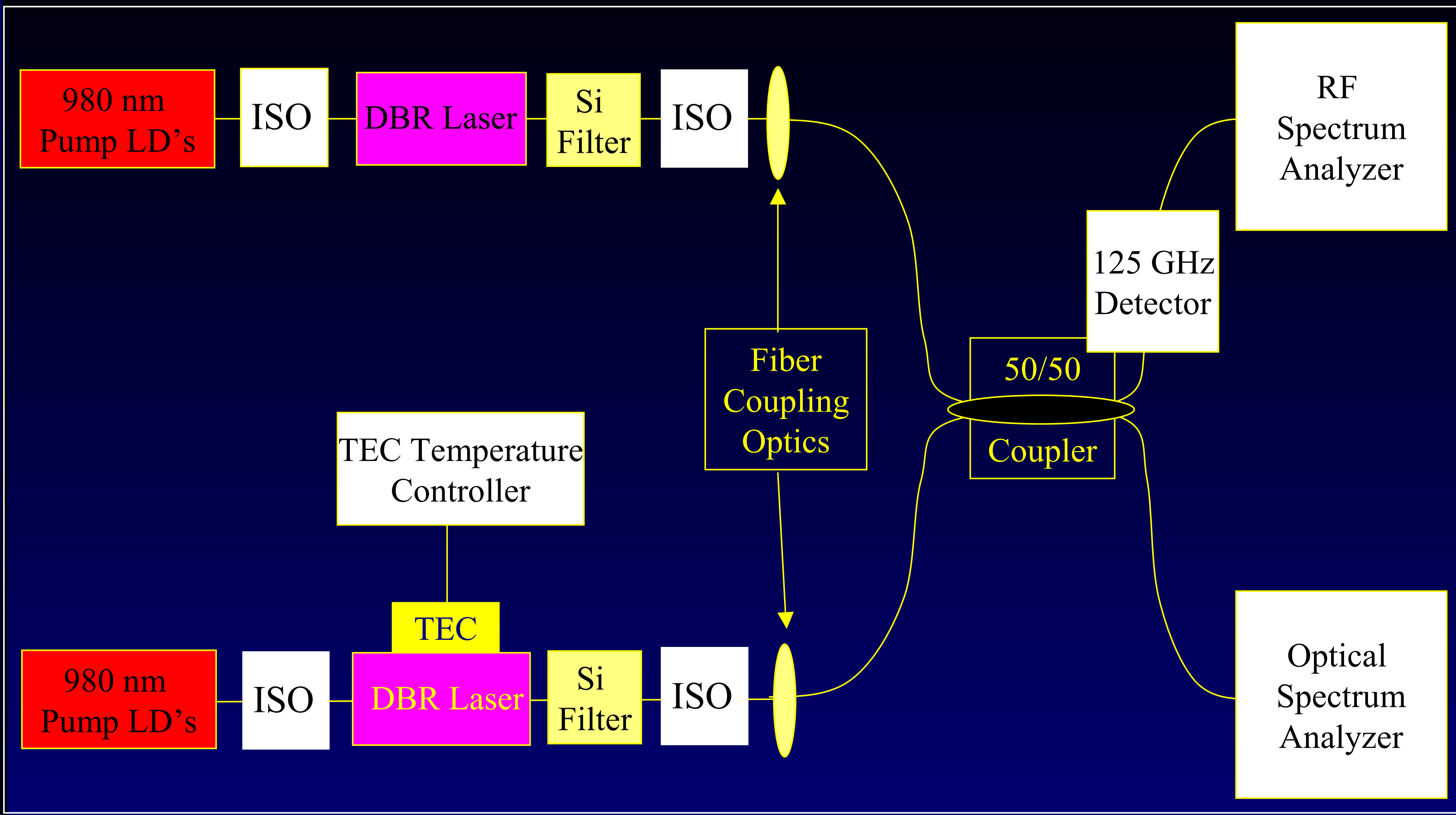
Schawlow-Townes Linewidth Limit



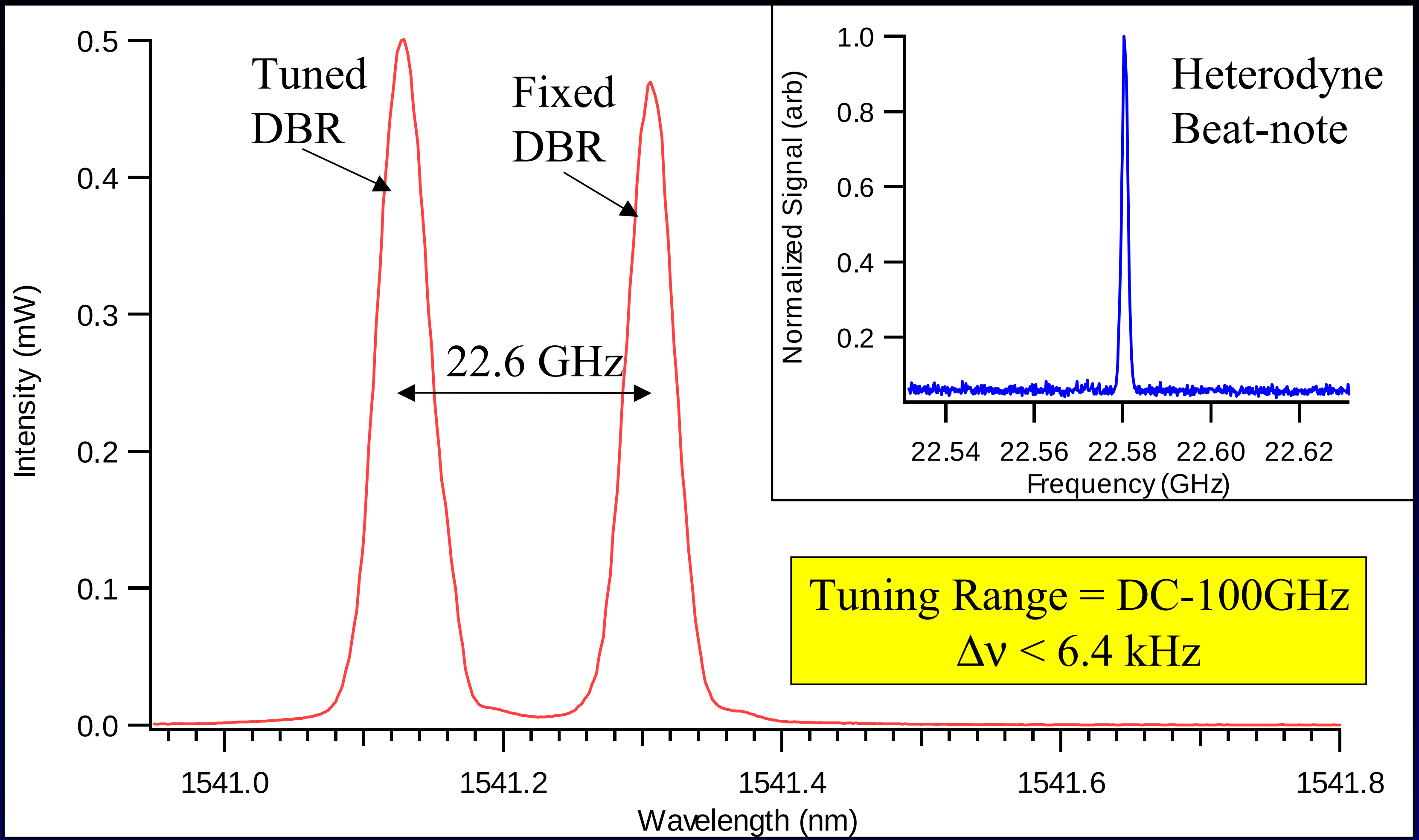
Linewidth Measurement



Optical Heterodyne Set-up



Optical RF & Microwave Frequency Generation



Tuning Range = DC-100GHz
$\Delta\nu$ < 6.4 kHz

Applications for AOSP

- All optical microwave and RF signal generation.
  - 1 Hz stability with phase lock to local oscillator.
  - Phase control.
- Laser sources for photonic crystal oscillators.
  - High-Q resonators with large dispersion require narrow linewidth sources.
- Other wavelengths available
  - 980 nm, 1050 nm, 1350 nm
- Compact size

Acknowledgements

-NIST Internal funding